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RESEARCH PAPER

Carbon pool structure and carbon density of soil in *Pinus koraiensis* plantation ecosystem

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Abstract: The organic carbon contents, carbon density and carbon storage of the soil in the *Pinus koraiensis* plantation ecosystem were investigated in Maoershan experimental forest farm, Shangzhi County, Heilongjiang, on the west slope of the Zhangguangcai Mountains in northeastern China for providing data to evaluation of the carbon balance in forest ecosystem of northeastern China. These soil carbon indicators were measured in three forest types, pure *P. koraiensis* plantation, *P. koraiensis* and *Betula platyphylla* mixed forest, and the *P. koraiensis* and *Quercus mongolica* mixed forest. The soil carbon pool consisted of four compartments, namely L layer, F layer, H layer and B layer. With variance analysis, we found that both organic carbon content and carbon density of the soil were significantly affected by forest types, soil compartments and slope positions. The highest soil carbon density (278.63 $Mg·ha^{-1}$).was observed in the mixed forest of *P. koraiensis* and *Q. mongolica*. The B layer had the highest carbon density (212.28 $Mg·ha^{-1}$) among all the soil compartments. In terms of slope position, the highest soil carbon density (394.18 $Mg·ha^{-1}$) presented in the low slope. Besides, soil carbon content and carbon density had a marked change with the organic matter content and vertical depth of the soil in each compartment. The results of this study implied that in the temperate humid region, the mixed ecosystem of regional *Pinus koraiensis* plantations and natural forest had relatively high carbon storage capability.

Keywords: soil carbon pool; soil carbon density; soil carbon content; *Pinus koraiensis plantation ecosystem*; mixed forest

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Introduction

The organic carbon pool of the soil as a major part of the global carbon circulation plays an important role in the research of global changes. It is estimated that 68–77Gt carbon are involved in respiration of soil every year (Bond et al. 2004). The carbon pool capacities of the biosphere, air and the soil, which are all active circles, are 560 Pg, 760 Pg and 2500 Pg, respectively (the organic carbon pool capacity is 1550 Pg, whereas the inorganic carbon pool capacity is 950 Pg). (Raich and Potter 1995) The carbon pool of the soil is 3.3 and 4.5 times that of the air and the biosphere, respectively (Wang et al 2009). Clearly, the carbon pool of the soil plays a crucial part in the global carbon circulation; hence, the carbon balance of the soil in the forest ecosystem plays an irreplaceable role in the global carbon balance (Zhou et al .2000). Therefore, the soil carbon research of the northeastern forest ecosystem is of significance for evaluating the carbon balance. In the present study, we measured the soil carbon contents and carbon density in the zonal *Pinus koraiensis* plantation ecosystem of the temperate region, with an attempt to seek out the carbon storing capability and the changing law for assessing the function and position of Chinese temperate forest ecosystem in the global carbon circulation (Li et al .2000).

Materials and methods

Study area

The study was conducted in the *Pinus koraiensis* plantations at the experimental station of Laoshan plantation of Morshan Maoershan Experimental Forest Farm (affiliated to Northeast Forestry University), Shangzhi County, Heilongjiang, China. This area was a part of White Mountain in the west of Zhangguangcai Mountains, with an average elevation of 300 m a.s.l. and an average gradient of 10–15°. The climate was of continental features in the temperate humid region, with an average annual temperature of 2.8ºC, average annual humidity of 70%, annual accumulated temperature (≥ 10 ºC) of 2582.3ºC, and an annual precipita-

tion of 723.8 mm. The zonal soil was dark brown soil. Forest vegetation is the mosaic distributions of natural broad-leaved trees and conifer plantations.

Measuring of experimental forest

The experimental forest was a 42-year-old *Pinus koraiensis* plantation, which was planted in April, 1966, with a plant and row spacing of 1.5m ×1.5m and planting density of 4400 trees/ha. Three types of plantations have been cultivated form the experimental forest for different functional purposes, including the pure *P. koraiensis* plantations, mixed forest of *P. koraiensis* plantations and natural *Btula platyphylla*, and the mixed forest of *P. koraiensis* plantations and natural *Quercus mongolica*. The *B. platyphylla* and the *Q. mongolica* were introduced species by natural regeneration. Thus, the *P. koraiensis* plantation has developed into a more stable forest ecosystem after the mixed with *B. platyphylla and Q. mongolica.* The basic data of the experimental forests are given in Table 1.

Table 1. The general survey of the experimental forests in the Laoshan plantation experimental station of Maoershan experimental forest farm, Shangzhi County, Heilongjiang, China

Forest types	Tree species	Tree ages	Soil	Diameter at breast height(cm)	Density (tree·ha^{-1})	Growing Stock (m^3/ha)	Community Composition
The *Pinus koraiensis* plantations	*P. koraiensis*	42 years	Dark brown soil	17.90	1680	169.10	*P. koraiensis* 10
The mixed forest of *Pinus koraiensis*	*P. koraiensis*	42 years	Dark brown soil	15.30	1440	117.05	*P. koraiensis* 7
And *Btula platyphylla*	*B. platyphylla*	35-45 years		16.70	640	67.8	*B. platyphylla* 2
	Total				2080	184.85	Other 1
The mixed forest of *Pinus koraiensis*	*P. koraiensis*	42 years	Dark brown soil	14.30	1440	123.65	*P. koraiensis* 7
And *Quercus mongolica*	*Q. momgolica*	35-45 years		15.30	700	55.37	*Q. momgolica* 2
	Total				2140	179.02	Other 1

Three sample plots (with an area of 500 m² for each) were set up for each type of forest (pure *P. koraiensis* plantation, *P. koraiensis* and *B. platyphylla* mixed forest, and the *P. koraiensis* and *Quercus mongolica* mixed forest. Every tree in the sample plot was investigated for diameter at breast height, height, and the dominant height (Table 1).

Soil measurement

Five squares (31.7 cm×31.7cm in size) were evenly set in each sample plot. The soil was divided into four layers, i.e., L layer, F layer, H layer and B layer (mineral soil), by the method of Zhang & Xu (1986) (Fig. 1), and the vertical depth of the square and the thickness of each layer were measured. These soil layers were naturally formed due to different storage capabilities, decomposition and different transferring ability of organic matters. The organic matters of each layer were weighed and the organic matter storage per hectare was calculated. As for the B layer, we did the same calculation based on the soil capacity. Given that each layer had its capacity, vertical depth and the function of storing and transferring carbon, we called each layer a carbon compartment.

After the sample were oven-dried at 105ºC for 8−10 h, the storage of each layer could be calculated according to the following equation: K_1 =dry weight/wet weight，K_1 is the conversion coefficient for measuring the amount of water (Zhang and Xu 1986).

Analysis method

After pre-processed, the samples of organic matter and soil of each layer were examined for their organic carbon content in the soil laboratory of Northeast Forestry University.

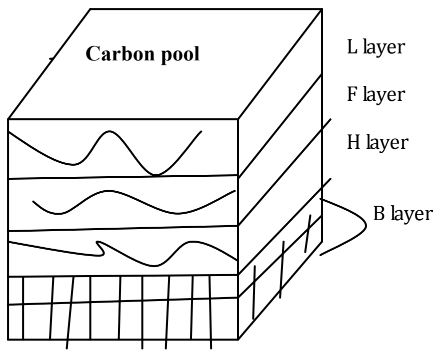

Fig. 1 The sketch map of different compartments in the experimental square

Result and discussion

Structure and function of the soil carbon pool in *P. koraiensis* plantations ecosystem

The soil in the *Pinus koraiensis* forest was the largest carbon pool in the *Pinus koraiensis* plantations ecosystem (Yu et al. 2003). The thickness, vertical depth, capacity and the carbon storage varied significantly among different layers (Table 2). The existing organic matters in L layer were still in the original state of litter, with a vertical depth of 0.027 m, and the capacity was in range of 240–340 m^3/ha. Primary function of L layer is to store forest vegetation litters and other organic residues and to transfer and input carbon. F layer under L layer had a little of organic matters decomposed. Its vertical depth was 0.048–0.061 m and its capacity was 243–280 m³/ha. F layer mainly dealt with the breaking down process of mineralized organic matters, the car-

bon transferring, and providing necessary condition for H layer. For H layer, all the organic matters were broken down and become humus layer, with a vertical depth of 0.140–0.166 m and the capacity of 870−1050 m³/ha. H layer stores humus and carbon, and it mineralize to release nutrients and produces new humus. H layer services as the best layer to store carbon. B layer, under H layer and above the lithic contact, had the largest capacity (4390−5053m³/ha) among the four layers, with a vertical depth of 0.569–0.646 m. In spite of its low organic matter content, the storage amounted to over 70% of the total. B layer is regarded as the largest carbon pool layer of the forest soil and possesses the biggest potential of storage. The dynamic process of organic substances, decomposing, storing and transferring from L layer down to B layer, keeps the balance of carbon input. It was concluded that each layer with different location and various capacities possesses its unique function and can not be replaced by any other layer. Therefore, the soil carbon pool with a complete systematical structure in the *Pinus koraiensis* plantation was completely formed.

Table 2. The carbon pool structures of different types of forests in *Pinus koraiensis* plantation ecosystem at Maoershan experimental forest farm, Shangzhi County, Heilongjiang, China

Forest type	Structural capacity	Vertical depth(m)	Capacity ($m^3 \cdot ha^{-1}$)	PCC (%)
Pinus koraiensis plantation	L layer	0.027	270	3.72
	F layer	0.055	280	3.76
	H layer	0.142	870	14.3
	B layer	0.581	4390	78.23
	Total	0.581	5810	100
The mixed forest of *P. koraiensis* and *B. platyphylla*	L layer	0.024	240	3.72
	F layer	0.048	243	3.26
	H layer	0.14	923.33	14.3
	B layer	0.646	5053	78.22
	Total	0.646	6459.33	100
The mixed forest of *P. koraiensis* and *Q. mongolica*	L layer	0.034	340	5.94
	F layer	0.061	274	4.78
	H layer	0.166	1050	18.33
	B layer	0.569	5033	70.42
	Total	0.569	6697	100

PCC=the proportion of the compartment capacity against the whole (%)

Feature analysis of organic carbon contents classification in the soil

Both the forest types and the soil layers would have obvious impacts on the organic carbon contents in the soil. Therefore, we conducted the two-factor variance analysis according to the statistics offered by Table 3. By factor A referring to forest type and factor B referring to soil layer, we constructed a variance analysis table based on the mathematical model of the two-factor variance analysis and results were presented in Table 4.

Eeffect of forest types on carbon contents of soil

Different types of forests had tremendously different influence on the soil carbon content just as the indicator F_A and $F_{0.05}$ illuminated. Among the three forest types, *P. koraiensis* and *Q. mongolica* mixed forest had the highest (23.170%) soil organic carbon content, 2.205% higher than that of the mixed forest of *P. koraiensis* and *B. platyphylla* and 24.061% higher than that of the pure *P. koraiensis* plantations. No significant difference was observed in carbon contents between the two mixed forests; however, the difference between the mixed forest and the pure *Pinus koraiensis* forest was evident due the fact that the soil in mixed forests contained an amount of litters of natural broad-leaved trees, which contained more carbon than that of the pure forest. From this perspective, more planted mixed forests of *Pinus koraiensis* and other natural trees should be cultivated to establish stable and effective forest ecosystem so as to raise the organic carbon content in each compartment of the soil carbon pool. (Table 3)

Table 3. The carbon content and density in the soil carbon pool in *Pinus koraiensis* plantation ecosystem at Maoershan experimental forest farm, Shangzhi County, Heilongjiang, China

Soil Layer	Soil compartment				
	Organic matter Storage ($t \cdot h\ a^{-1}$)	Organic matter Content (%)	Carbon Contents (%)	Carbon density ($Mg \cdot h\ a^{-1}$)	Carbon density Against the whole (%)
Pinus koraiensis plantations					
L layer	23.23 + 0.475	62.091	36.008	8.359+0.493	3.52
F layer	36.17 + 0.399	33.012	21.468	7.667+ 0.39	3.23
H layer	531.500 +0.523	15.515	9.033	48.16+0.251	20.26
B layer	4481.370 +143	6.674	3.871	173.470 +19.780	72.99
Average		29.323	17.595		
Total	5072.27			237.656	100
Mixed forest of *Pinus koraiensis* and B*tula platyphylla*					
L layer	18.52 + 0.381	79.484	46.101	8.567	3.37
F layer	39.7 + 0.387	57.231	33.2	13.252	5.21
H layer	533.48 ± 0.402	15.573	7.7	50.958	20.05
B layer	4899.66 ±120.00	6.2	3.637	181.459	71.37
Average		39.622	22.659		
Total	5491.36			254.196	100
Mixed forest of *Pinus koraiensis* and *Quercus mongolica*					
L layer	25.923 +0.247	79.08	45.87	11.965±0.690	4.29
F layer	45.6 +0.332	58.046	33.669	15.478±0.495	5.56
H layer	507.52 ±0.421	13.955	8.096	38.91±1.210	13.96
B layer	4914.0 ±131.00	8.697	5.044	212.276±18.61	76.19
Average		39.945	23.17		
Total	5583.043			278.629	100

Table 4. Two-factor variance analysis of organic carbon content for different forest types and different soil layers in *Pinus koraiensis* plantation ecosystem

Variance source	Deviation sum of squares	Degree of freedom	Mean square	F value	Cut-off value
Factor A	L_A=1890.04	2	S_A^2=945.02	F_A=16.03	$F_{0.05(2.6)}$=5.14
Factor B	L_B=876.42	3	S_B^2 SB=292.14	F_B=4.95	$F_{0.05(3.6)}$=4.76
Errors	L_e=353.67	6	S_e^2=58.95		
Total	L_T=3120.13	11			

Effect of soil carbon compartment on organic carbon content

The carbon contents in different compartments varied significantly and follows the rule of L layer (36.008%–46.101%) > F

layer (21.468%–33.669%) > H layer (7.700%–9.033%) > B layer (3.670%–5.044%), indicating that the carbon content become lower with the deepening of soil compartments (Table 3).

More organic matters were accumulated in L layer and F layer, since some forest vegetation litters and other organic residues fall on the surface of the soil every year. With the supplement of new organic matters each year, which contains more carbon, the organic carbon content of L layer and F layer had an annual increase, while that of H layer and B layer stayed low (Ge et al. 2002).

The effect of slope positions on the soil organic carbon content

The slope position refers to the position on a same slope. We conducted two-factor variance analysis based on the statistics in Table 5, factor A represents the forest type and factor B represents the slope position, and the result was shown in Table 6.

Table 5. The influence of slope positions on the carbon content and carbon density of soil in *Pinus Koraiensis* plantation ecosystem at Maoershan experimental forest farm, Shangzhi County, Heilongjiang, China

Forest Types	Slope positions	L layer		F layer		H layer		B layer		Total	
		Carbon Content (%)	Carbon Density ($Mg \cdot ha^{-1}$)	Carbon Content (%)	Carbon Density ($Mg \cdot ha^{-1}$)	Carbon Content (%)	Carbon Density ($Mg \cdot ha^{-1}$)	Carbon Content (%)	Carbon Density ($Mg \cdot ha^{-1}$)	Carbon Content (%)	Carbon Density ($Mg \cdot ha^{-1}$)
Pinus koraiensis plantation	Upper slope	27.780	5.491	19.357	7.404	6.687	33.709	1.760	101.059	13.999	147.663
	Middle slope	42.585	6.707	23.580	6.272	10.910	55.445	4.575	205.793	20.411	274.20
	Low slope	37.685	12.879	21.468	9.325	9.503	55.326	5.279	248.363	18.477	316.569
	Average										246.14
Mixed forest of *P. koraiensis* and *B. platyphylla*	Upper slope	44.697	6.883	39.066	12.032	4.575	23.585	1.760	83.737	12.524	126.277
	Middle slope	45.400	8.240	36.250	19.031	10.206	57.329	4.33	212.270	24.402	297.87
	Low slope	48.216	10.077	24.284	8.694	12.318	71.839	5.210	245.17	22.50	335.727
	Average										253.29
Mixed forest of *P. koraiensis* and *Q. mongolica*	Upper slope	48.920	16.951	36.250	17.908	9.503	38.298	3.831	144.512	24.636	217.669
	Middle slope	48.216	9.282	38.361	17.493	3.168	17.947	4..558	209.255	23.575	253.977
	Low slope	40.424	9.661	26.396	11.034	11.614	60.458	6.687	283.061	21.278	394.184
	Average										288.61

Table 6. Variance analysis of organic carbon content for different slope positions and different forest types in *Pinus koraiensis* plantation ecosystem

Variance source	Deviation sum Of squares	Degree of freedom	Mean square	F value	Cut-off value
Factor A	L_A=45.320	2	S_A^2=22.66	F_A=7.10	$F_{0.05(2.4)}$=6.94
Factor B	L_B=96.59	2	S_B^2=48.30	F_B=9.63	$F_{0.05(2.4)}$=6.94
Errors	L_e=12.760	4	S_e^2=3.19		
Total	L_T=154.67	8			

Variance analysis indicated that the forest types had a relatively more significant effect on the average organic carbon content of different slope positions in the soil carbon pool, following the rule of the mixed forest of *P. koraiensis* and *Q. mongolica* > the mixed forest of *P. koraiensis* and *B. platyphylla* > the *P. koraiensis* plantations, in terms of the carbon content. It was because the organic matter content in the mixed forest of *P. koraiensis* and *Q. mongolica* was 26.59% higher than that of the pure *P. koraiensis* forest and 0.08% higher than that of the mixed forest of *P. koraiensis* and *B. platyphylla*, revealing the feature of mixed forest—rich of organic matters and reactive organic carbon.

Besides, the slope positions had significant effect on organic carbon content of soil, following the rule of low slope > middle slope > upper slope. The soil carbon content at low slope was 25.27% higher than that of the upper slope and 8.96% higher than that of the middle slope (Table 5). The experimental forest was a small watershed system with different ecological factors and disparate bio-function in each slope position. The upper slope lost many organic and inorganic nutrients due to erosion by the rain and the runoff. Although the upper slope possesses a large quantity of litter water, it cannot alter the rule of nutrients flowing from up slope to middle slope and low slope, thus it is called "the nutrients-lost zone". The middle slope that is less steep than the upper slope not only loss but also gains nutrients, so it is called "the nutrients transition zone". Due to its flat landform, the low slope receives an amount of nutrients from the upper and middle slopes and also accumulated nutrients, named "the rich nutrient zone". In addition, the wind also helps to take the litter from the upper part to the low part of the slope, leading to the natural increase of organic matters on the low slope.

Carbon density of soil in *P. koraiensis* ecosystems

Effect of forest types on carbon density

Carbon density refers to the carbon storage per hectare and it is a primary indicator of the carbon storage in the carbon pool of forest soil. The higher the carbon density is, the larger the carbon storage is. According to the statistics in Table 3, we conducted two-factor variance analysis. Factor A represents the forest type and factor B represents the compartment of soil carbon pool (Table 7). The results show that forest types had relatively significant effect on carbon density. The carbon density of the mixed forest of *P. koraienisis* and *Q. mongolica* was 8.77% higher than that of the mixed forest of *P. koraiensis* and *B. platyphylla*, and 14.70% higher than that of the pure *Pinus koraiensis* forest.

Effect of soil carbon pool compartments on carbon density

The carbon density in different carbon pool compartments of the forest soil varied tremendously (Table 7). The carbon density of B layer was the highest, with an average of 189.07 Mg/ha, accounting for 73.63% of the total (Table 3), followed by H layer (45.99 Mg/ha, 17.91%) and F layer (12.13 Mg/ha, 4.72%), while that of L layer was the lowest (9.63 Mg/ha, 3.75%). The carbon density in different soil layers was in the order of B layer > H layer > F layer > L layer, indicating that the carbon density increased with the deepening of soil layers (Raich and Tufekcioglu 2000). Though the carbon content was high in L layer, the carbon density was still very low due to its small capacity, only accounting for 3.37%–4.29% of the total. As for B layer, in spite of the low carbon content (4.01–5.50%), its capacity was large, so was its carbon density, accounting for 71.19%–76.19% of the total.

Table 7. Two-factor variance analysis of soil carbon density for different forest types and soil carbon density in *Pinus koraiensis* plantation ecosystem

Variance Source	Deviation sum Of squares	Degree of freedom	Mean square	F value	Cut-off Value
Factor A	L_A=20769.78	2	S_A^2=10384.89	F_A=7.98	$F_{0.05(2.6)}$=5.14
Factor B	L_B=36256.94	3	S_B^2=12085.65	F_B=9.29	$F_{0.05(3.6)}$=4.76
Errors	L_e=7807.55	6	S_e^2=1301.26		
Total	64834.27				

The effect of slope positions on the carbon density

According to Table 5, we conducted the two-factor variance analysis of the forest types and slope positions (Table 8). Factor A represented the forest type and factor B represented the slope positions (including upper slope, middle slope and low slope).

Table 8. Two-factor variance analysis of carbon density for different forest types and different slope positions in *Pinus Koraiensis* plantation ecosystem

Variance source	Deviation sum Of squares	Degree of freedom	Mean square	F value	Cut-off value
Factor A	L_A=7000.50	2	S_A^2=3500.25	F_A=7.83	$F_{0.05(2.4)}$=6.94
Factor B	L_B=52077.60	2	S_B^2=26038.80	F_B=58.26	$F_{0.05(2.4)}$=6.94
Errors	L_e=1787.60	4	S_e^2=446.90		
Total	L_T=60865.70				

Result shows that the different forest types had significant influence on the soil carbon density at different slope positions. Among the three types of forests, the mixed forest of *P. koraienisis* and *Q. mongolica* had the highest soil carbon density, with an average of 288.6 Mg/ha, 12.23% higher than that of the mixed forest of *P. koraienisis* and *B. platyphylla* and 14.70% higher than that of the pure *P. koraienisis* forest. Both the carbon content and the organic matter content of the mixed forest of *P. koraiensis* and *Q. mongolica* were higher than that of the mixed forest of *P. koraiensis* and *B. platyphylla* or the pure *P. koraiensis* forest, which manifested the edaphic feature of the mixed forest of *P. koraiensis* and *Q. mongolica*. In addition, the carbon content and the organic substance content were both essential factors in increasing the carbon density (Raich and Schlesinger 1992). The result of $F_B > F_{0.05(2.4)}$ (Table 8) indicated that the slope positions had significant influence on the carbon density of different soil compartments, following the rule of low slope > middle slope > up slope. The carbon density at low slope was 53.02% higher than that at the upper slope and 21.07% higher than that at the middle slope. This is because the ecological environment of each slope position was quite different. On the upper slope, the ground temperature is relatively high but the water is inadequate, so litter is easy to decompose. As for the low slope, the low ground temperature and the thick soil layer lead to the slow decomposition process. Hence, the nutrients are concentrated on the low slope and made it fruitful.

Dynamic process of carbon content and carbon density in soil carbon pool

Correlation analysis between the carbon content and the vertical depth of soil compartments

The vertical depth of soil compartments (m) in Table 2 closely relates to the corresponding carbon content (%) in Table 3, which can be shown by the exponential equation ($Y=ae^{bx}$). The illustrations are as follows:

(1) The exponential curve equation about the pure *P. koraiensis* plantation is Y=84.798$e^{0.7556X}$, R^2=0.9882；

(2) The exponential curve equation about the mixed forest of *P. koraiensis* and *B. platyphylla* is Y=139.29 $e^{0.908X}$， R^2=0.9505；

(3) The exponential curve equation about the mixed forest of *P. koraiensis* and *Q. mongolica* is Y=118.51$e^{0.8048X}$， R^2=0.9362。

In these equations, Y refers to the carbon content of different forest types; X refers to the vertical depth (m) of soil compartments, "a" and "b" are the coefficients of the exponential regression equation, R represents the relative coefficient. Through the above analysis, we found that the soil carbon contents of different forest types decrease with the growing of vertical depth of the soil compartments. The main reason lies in the fact that the organic matter content is high in the upper soil compartment (L layer, F layer), leading to a high carbon content rate there. Whereas the organic matter contents of H layer and B layer at the lower compartments are low, resulting in lower carbon content (Landsberg and Waring 1997). The exponential curve regression equation shows the features and changing rules of the soil carbon content (Fig. 2).

Correlation analysis between soil carbon density and vertical depth of soil compartments

The vertical depth of soil compartments in Table 2 and the corresponding carbon density in Table 3 can be fitted respectively by an exponential curve equation as follows:

(1) The exponential curve equation for the pure forest of *P. koraiensis* is Y=1.7573$e^{1.0936X}$， R^2=0.8852；

(2) The exponential curve equation for the mixed forest of *P. koraiensis* and *B. platyphylla* is Y=2.3152 $e^{1.0506X}$, R^2=0.9612；

(2) The exponential curve equation for the mixed forest of

P. koraiensis and *Q. mongolica* is Y=3.2309 $e^{0.955X}$, R^2=0.8979.

In conclusion, the soil carbon density increases with the deepening of the soil compartments. Despite of the high carbon content fraction of the upper compartments, the small capacity of them leads to the low carbon density (Frank et al 2002). On the contrary, the capacity of lower compartments is large and the carbon density is high, in spite of the low carbon content rate. All these showed the changing rules and features of the carbon density.

The curve of the carbon content and the curve of the carbon density are totally different, but they closely link to each other. Two curves go in the opposite directions with the changing of the vertical depth of soil compartments, which has practical significance to the research of enhancing the carbon storage as well as the carbon content of the soil carbon pool (Fig. 3).

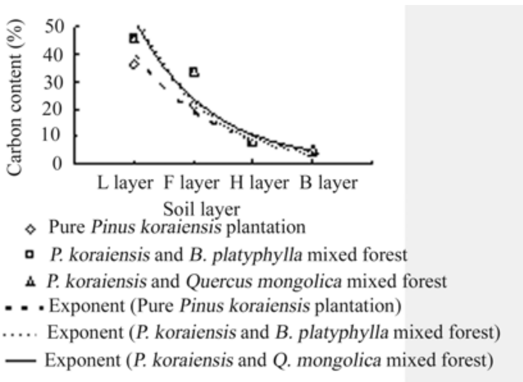

Fig. 2 Correlations of carbon content and soil layer depth in *Pinus Koraiensis* plantation ecosystem

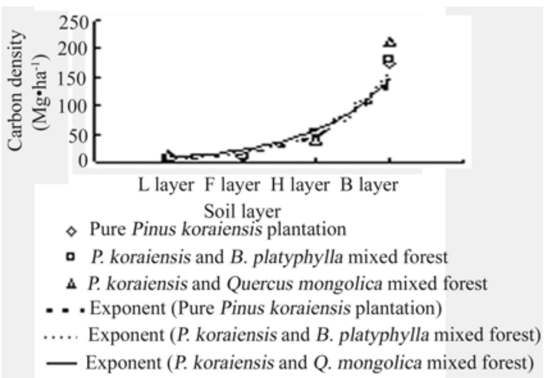

Fig. 3 relationship of carbon density and soil layer depth in *Pinus Koraiensis* plantation ecosystem

Conclusion

The forest soil as a carbon pool, consisted of four compartments, namely L layer, F layer, H layer and B layer and they all have the function of absorbing, storing and transferring carbon, serving as important components of the carbon pool in the *P. koraiensis* plantations ecosystem, following the rule of B layer > H layer > F layer > L layer in term of capacity.

Through the two-factor variance analysis, we found that in the *Pinus koraiensis* plantations ecosystem, both soil compartments and slope positions were decisive factors in the aspect of affecting the organic carbon content as well as the organic carbon density. In term of forest types, the mixed forest of *P. koraiensis* and *Q. mongolica* had the highest soil carbon content (23.17%), and its soil carbon density was 278.629 Mg/ha, with an annual average of 6.634 Mg/ha. Among different soil compartments, the carbon density of B layer was the highest (212.276 Mg/ha), with an annual average of 5.054 Mg/ha. For slope positions, the soil carbon density at low slope was the highest (394.184 Mg/ha), with an annual average of 9.709 Mg/ha. These results demonstrated that the carbon pool in different depths has different carbon storing capabilities.

With the deepening of the soil compartments, the organic carbon content of the soil decreased while the carbon density increased. This phenomenon reflected the changing pattern of carbon storing capability in the soil carbon pool.

In the temperate humid region, the zonal mixed forests of *Pinus koraiensis* and other natural broad-leaved trees should be cultivated in a large scope since they have excellent and strong carbon storing capability.

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